A Simulation Analysis of the Time-dependent Roles of Phytoplankton and CDOM in Effecting the 3-dimensional Structure of Inherent Optical Properties on the West Florida Shelf

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LONG-TERM GOAL

Construction and validation of coupled physical/ecological/bio-optical models of phytoplankton and colored dissolved organic matter on continental shelves to predict both the time-dependent, spatially-heterogeneous inherent optical properties [IOP] of subsurface waters and the consequent hyperspectral water leaving radiances [L_w] at the surface.

OBJECTIVES

Using the West Florida shelf as an initial test case, where field validation data have been obtained in the ONR HyCODE [Hyperspectral Coastal Ocean Dynamics Experiment], ONR AUV [Autonomous Underwater Vehicle], NOAA/EPA ECOHAB [Ecology and Oceanography of Harmful Algal Blooms], and MMS NEGOM [NorthEastern Gulf of Mexico] projects, my objective is to couple a model of nine functional groups of competing microalgae to ones of both physical forcing at different regional/local scales and of the consequent bio-optical signals sensed by aircraft and satellites for prediction of 3-dimensional IOP and their surface L_w over time.

These ONR studies focus on a control volume, bounded by ADCP arrays, which extends between the 10-m and 50-m isobaths, along the Florida coast from Tampa Bay to Charlotte Harbor. The study site was sampled at monthly intervals, with continuous underway measurements out to the shelf-break of temperature, salinity, *in vivo* chlorophyll fluorescence, CDOM, and light transmission, from June 1998 to October 2001. At discrete stations, additional data have been collected on distributions of NO_3, NO_2, PO_4, SiO_4, Fe, DOP, DON, DIC, DOC, chlorophyll, phaeopigments, PN, PC, PP, del^{15}N of PN, and counts of all dominant phytoplankton and mesozooplankton species.

Upstream boundary conditions of the coupled models on the West Florida shelf are derived from NEGOM quarterly surveys of hydrographic, nutrient, HPLC pigment, and CDOM properties in May, August, and November 1998-2000, taken between Tampa Bay and the Mississippi River delta. They also provide seasonal three-dimensional composites of the HyCODE/ ECOHAB/ NEGOM data sets (Figure 1), which yield offshore boundary conditions of Loop Current forcing.

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During 2000-2001, additional interior ADCP arrays within the control volume supported a suite of moored optical sensors. On supplemental cruises at 2-month intervals, other discrete measurements of turbidity, and spectral dependence of absorption, backscatter, water-leaving radiance, and light attenuation were made. Finally, during three AUV experiments in July, November 2000 and April 2001, SF_6 dispersion, nutrient tracer, and bio-optical studies were conducted in relation to aircraft overflights and underway sampling of plankton particles [OPC, LS] and images [SIPPER].

APPROACH

A traditional N-P-Z [Nutrient-Phytoplankton-Zooplankton] model with one state variable each to represent the plant and animal communities of oceanic waters is incapable of addressing bio-optically complex regions of the coastal zone. Competing functional groups of plankton on the West Florida shelf can all generate separate pigment stocks of >5.0 ug chl l^{-1}, i.e. spectrally-averaged attenuations of >0.09-0.29 m^{-1} depending upon packaging effects of cell size, in both the water column and the sediments. In this subtropical habitat, diatoms, microflagellates, toxic dinoflagellates, nitrogen-fixing cyanophytes, and benthic microflora each form episodic blooms, whose changing color signals are derived from physical supply of nutrients, aggregation processes, and differential losses of the algal populations. Riverine supply of terrestrial humic and fulvic acids, plankton release of marine CDOM, and local resuspension of organic and inorganic debris further complicate interpretation of remotely-sensed L_w.

With this goal of specification of IOP and L_w over time and space, the above field programs were designed to test a set of linked 3-dimensional circulation, phytoplankton/microflora succession, and spectrally resolving bio-optical numerical models, developed by a group of ONR-funded investigators, consisting of J.J. Walsh and R.H. Weisberg at USF [University of South Florida] and W.P. Bissett at FERI [Florida Environmental Research Institute]. Brief details of the other circulation and bio-optical models are presented in the section on related projects.

The model's state variables of the planktonic microalgal community are small and large diatoms, toxic and edible dinoflagellates, nitrogen-fixing *Trichodesmium*, coccolithophores, autotrophic microflagellates, and coccoid cyanophytes (Penta et al., 2001). Since chlorophyll biomass within the upper 0.5 cm of sediments can be 2-4 fold that of the overlying water column, with a five-fold seasonal variation on the West Florida shelf, the benthic microflora are included as another state variable. Light [spectral PAR], nutrient availability [NO_3, NH_4, N_2, PO_4, SiO_4, Fe, DOP, DON, DIC], and differential settling or grazing [heterotrophic flagellates, ciliates, copepods, meiobenthos] losses effect the outcome of competition and release of CDOM among the nine groups of microalgae.

WORK COMPLETED

To provide a numerical synthesis of these diverse data sets, we first completed retrospective simulation studies of the plankton sources of IOP and L_w over the last 40 years on the West Florida shelf (Walsh and Steidinger, 2001; Walsh et al. 2001a, b). Thus far, phytoplankton, nutrient, and hydrographic observations on the West Florida shelf have been compiled as a time series over 1957-1998 to develop the above plankton model, and its associated circulation and bio-optical models, prior to the next phase of validation with the 1999-2001 HyCODE data.

For example, we have used 1) one-dimensional models to specify the rules of engagement between the eight functional groups of phytoplankton during 1992 and 1998 (Walsh et al., 2001a; Penta et al., 2001), 2) two-dimensional models to explore the bio-optical consequences of their interaction with the microbial food web during 1998 (Bissett et al., 2001), and 3) three-dimensional models to predict their transport, landfall, and residence time within the first optical depth - as detected by satellite during 1979 and 1980 (Walsh et al., 2001b).

RESULTS

In our present models, limiting resources of light, nitrate, ammonium, DON, phosphate, DOP, iron, and silicate, as well as differential grazing pressures and sinking losses, allow the coexistence of nine functional groups of chromatically-adapted pelagic and benthic microalgae. Note that in our model of the West Florida shelf, CO_2 and N_2 are also state variables, but they are considered to be in excess of algal needs. From our initial simulation analyses, we find that diatoms win when estuarine and shelf-break supplies of nitrate are made available to our model's phytoplankton community, yielding 4-5 ug chl l^{-1} as observed - either as a surface signal from discharges of the Apalachicola River, or a near-bottom one from intrusions of Loop Current water. Benthic diatoms soon become Si-limited after fallout of the phytoplankton, but allow little influx of recyled nutrients back to the water column.

A numerical recipe for large red tides of 20-40 ug chl l^{-1} of *Gymnodinium breve* instead requires DON supplies, mediated by iron-starved, nitrogen-fixers in response to Saharan dust events (Lenes et al., 2001). Light-cued diel vertical migration of *G. breve*, in relation to seasonal changes of downwelling and upwelling flow fields, determines both their duration within the first optical depth as a remotely-sensed signal and the intensity of red tide landfalls along the barrier islands and beaches of West Florida (Walsh et al., 2001b). The coupled model's alongshore trajectory of *G. breve* at the surface and its onshore movement within the bottom Ekman layer match successive shipboard, helicopter, and shore observations of biomass in 1979 and 1980, but require frontal aggregations to effect red tide levels of abundance.

IMPACT/APPLICATIONS

Once these coupled models of IOP and L_w are validated with the extensive observations made during 1999-2001 at the West Florida shelf site, we would apply them to other ongoing ONR field studies: COBOP at Lee Stocking Island in the Bahamas and LEO-16 on the New Jersey shelf.

RELATED PROJECTS

With support from N000149810158, Bob Weisberg is using the Princeton Ocean Model [POM] both for analysis of the observed current fields on the West Florida shelf and to drive our plankton model (Walsh et al., 2001b). With support from N000149615024, Kent Fanning is providing validation data for the linked 3-dimensional circulation, phytoplankton/microflora succession, and bio-optical models, with nutrient measurements, e.g. Figure 1. Similarly, Rik Wanninkhof is providing estimates of the dispersion of the released tracer SF_6, during these Lagrangian nutrient studies. With support from N000149710006, Ken Carder is developing remote sensing algorithms for initial conditions of the multiple groups of phytoplankton in our models (Carder et al., 2001). Finally, with support from N000149810844, Paul Bissett is applying Ecological Simulation 2.0 [EcoSim 2.0] to the West Florida for predicting the daily changes in the spectral quality of the downwelling light field (Bissett et al., 2001). The daily IOP outputs are also coupled with the Hydrolight 4.0 radiative transfer code to predict the upwelling light field at 10:00 am each day. We are now in the process of merging POM and EcoSim 2.0 with the microalgal succession model to form a complete 3-dimensional, ecologically complex, bio-optical model of the West Florida Shelf for analysis of all the 1998-2001 data (Figure 1).

PUBLICATIONS

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